Fermilab

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2254

CHARGED M4 BEAM LINE

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A suggestion by the PAC[1] has resulted in a tentative design by C. N. Brown and A. L. Read[2] for a charged version of the M4 beam line which would also permit rapid conversion to neutral beam operation. We have restudied their design; the beam design presented here incorporates some changes which result in significant improvements in transmitted flux, maximum momentum, and economy of conversion. This beam has a transmission $\Delta\Omega(\Delta p/p) = 9.6 \times 10^{-8}$, which roughly represents a 14% momentum band in which the transmitted solid angle is $.66 \times 10^{-6}$ steradian. The constraint of maintaining the field linearity of quadrupoles allows operation to p = 160 GeV/c. By accepting some loss of image quality and/or solid angle, one can get to 210 GeV/c.

The accepted solid angle and maximum momentum are determined by the strongest quadrupole doublet which can fit in the pit in the Front End Hall. The remaining elements are arranged so that no further aperture limitation occurs. All remaining quadrupoles operate at lower field gradients than the input doublet. The first dipole produces momentum dispersion at the intermediate focus; two more dipoles return the beam to the neutral beam axis and produce zero transverse dispersion at the final focus.

The charged-neutral beam conversion involves only the horizontal motion of the collimators and dipoles in the 600' enclosure. All other elements lie on the neutral beam line. The beam is parallel to the axis between the 1000' and 1300' enclosures, which permits use of a differential Cerenkov counter.

Table I shows the beam line elements, as well as the changes which are to be made in the initial conversion from neutral to charged beam line. Figures 1 and 2, respectively, show the beam envelope in the vertical and horizontal planes.

Figure 3 shows the optic axis. Table II shows the operating fields at 200 GeV/c. For quadrupole gradients, divide by the pole tip radius of 3.81 cm. We summarize the essential features of this design and the design of Reference 2 as follows:

Parameter	Reference 2	This Beam
$\Delta\Omega(\Delta p/p)$	4.7×10^{-8} ster	9.6×10^{-8} ster
$\Delta\Omega(\Delta p = 0)$	$.41 \times 10^{-6}$ ster	$.66 \times 10^{-6}$ ster
$\Delta p/p$ FWHM	9%	11%
Max. Momentum for No Saturation of Quadrupoles	84 GeV/c	158 GeV/c
Max. Momentum	111 GeV/c	210 GeV/c
Size of Focus	.8 cm x 2.25 cm	See Figure 5

Figure 4 compares the solid angle transmitted by both beams as a function of momentum relative to the design momentum. Figure 5 shows vertical and horizontal profiles of the final focus. The shoulder on the right side of these curves is produced by high momentum particles which traverse the momentum defining slit because of chromatic aberration at the intermediate focus. A vertical slit at the intermediate focus removes the shoulder and reduces the transmitted flux by about 25%.

Within the constraints imposed by using 3" quadrupoles released from the single arm spectrometer, and by the available spaces for placing magnets in the M4 line, the present beam transmits the maximum possible flux up to the highest useful momentum for secondary beams from the Meson target. Further improvement would require better quadrupoles and excavation in the M4 line.

REFERENCES

[1]NALREP, NAL-74/8, July 1974, P. 16.

[2]Two Additional Charged Beams in the Meson Area. C. N. Brown and A. L. Read, Fermilab, TM-548, February 1975.

Table I

CHARGED M4 BEAM LINE ELEMENTS

Location	Ft.	Description	Initial Action
Front End Hall	246	Beam Stop	Move to 400'
	254	5-1.5-120 Dipole	Remove
	245	3Q120 Quadrupole	Add
	258	3Q120 Quadrupole	Add
400 Ft.	368	Fixed Collimator(½"x½")	Remove
	368	3Q60 Quadrupole	Add
	390	3 Muon Spoilers	Remove
	376	Fixed Collimator(2"x4")	Add
	380.5	Beam Stop	Move from Front End Hall
	383.5	5-1.5-60 Dipole	Add
600 Ft.	655	Horizontal Collimator	None
	661	Vertical Collimator	None
All elements move to convert to neutral beam	667	2 x 5-1.5-120 Dipoles	Remove
	643	Neutral Beam Stop	Add
	673.6	5-1.5-60 Dipole	Add
	680.1	5-1.5-60 Dipole	Add
1000 Ft.	1007.5	Horizontal Collimator	Move from 1013'
	1012.5	Vertical Collimator	Move from 1019'
	1018.5	5-3.0-60 Dipole	Add
	1025	3Q60 Quadrupole	Add
	1038	5-3.0-60 Dipole	Add
	1051.5	3Q60 Quadrupole	Add
1300 Ft.	1317.5	3Q60 Quadrupole	Add
	1347.5	3Q60 Quadrupole	Add

Note: All distances in feet to element center.

Table II

CHARGED M4 BEAM LINE ELEMENTS

Location	Ft.	Description	Field At Pole Tip
Front End Hall	245	3Q120 Quadrupole	-7.15 kG
	258	3Q120 Quadrupole	6.72
400 Ft.	368	3Q60 Quadrupole	1.00
	376	Fixed Collimator (2"x4")	
	380.5	Beam Stop	
	383.5	5-1.5-60 Dipole	4.68
600 Ft.	643	Neutral Beam Stop	
	655	Horizontal Collimator	
All elements move to convert to neutral beam	661	Vertical Collimator	
	673.6	5-1.5-60 Dipole	4.68
	680.1	5-1.5-60 Dipole	4.24
1000 Ft.	1007.5	Horizontal Collimator	
	1012.5	Vertical Collimator	
	1018.5	5-3.0-60 Dipole	4.24
	1025	3Q60 Quadrupole	6.09
	1038	5-3.0-60 Dipole	0.0
	1051.5	3Q60 Quadrupole	-5.70
1300 Ft.	1317.5	3Q60 Quadrupole	-4.72
	1347.5	3Q60 Quadrupole	5.04
M4 Pit	1792	Final Focus	

Note: All distances in feet to center of element.
All fields are calculated for 200 GeV/c.

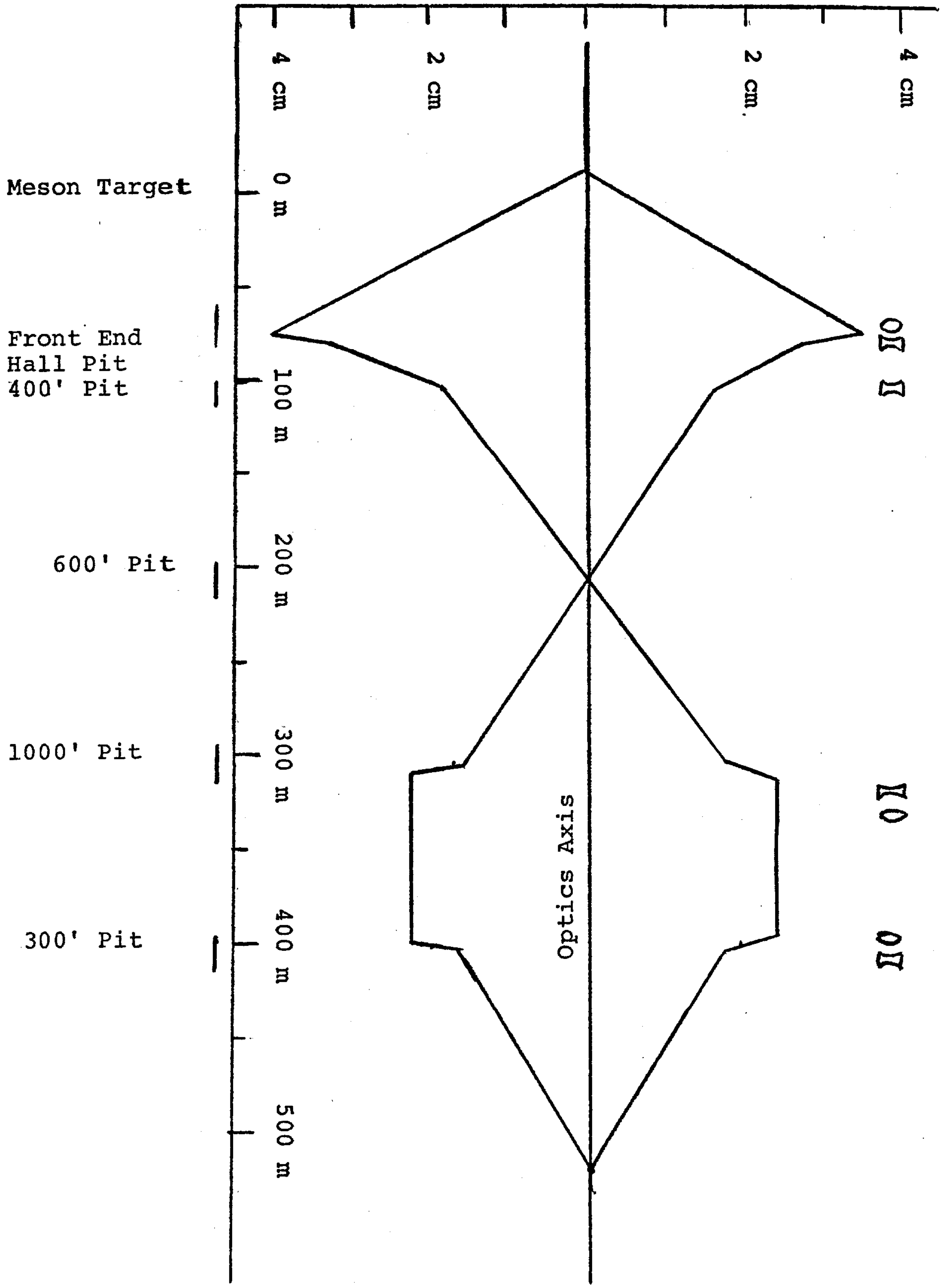

Figure 1

BEAM ENVELOPE - VERTICAL PLANE

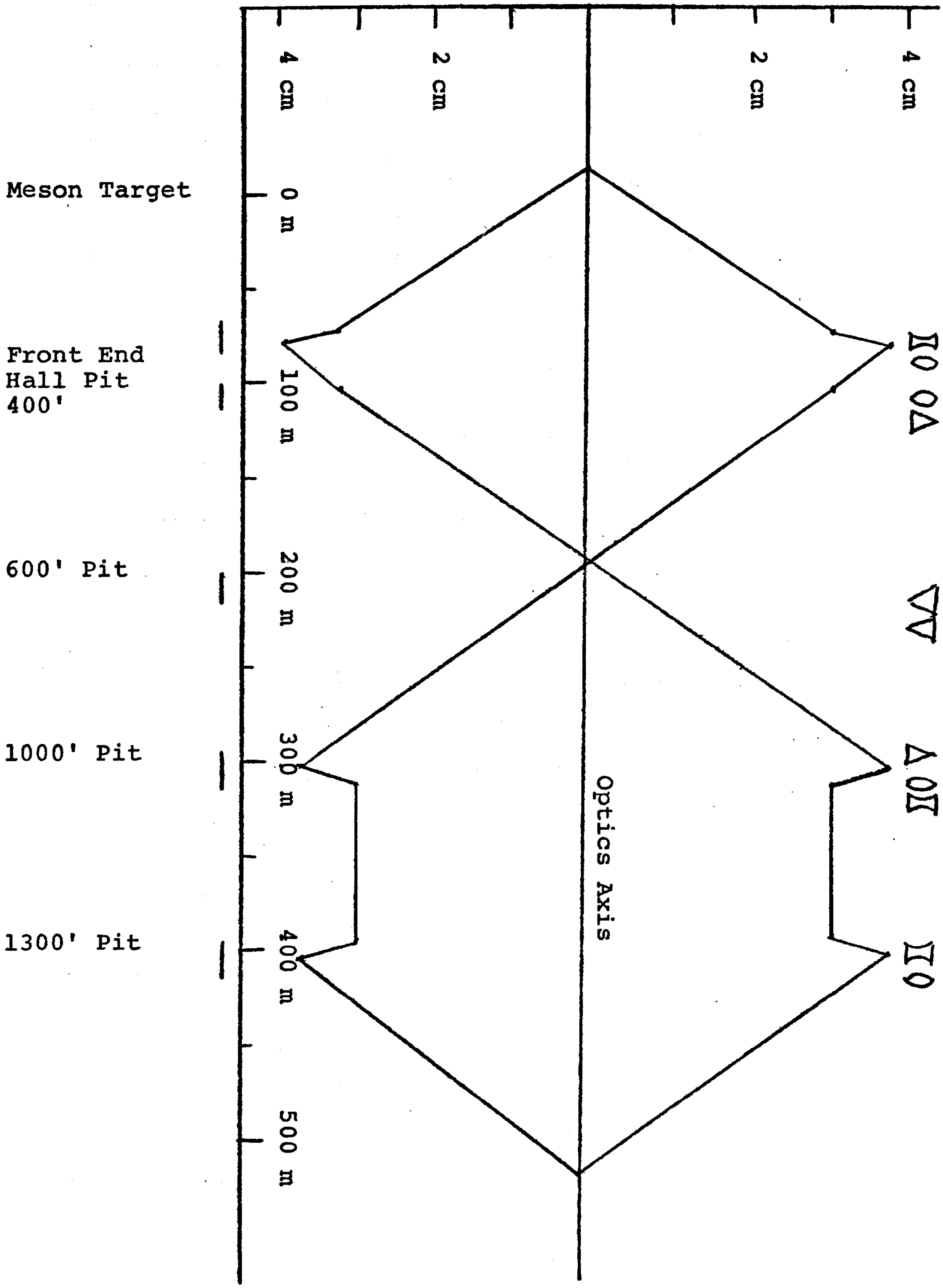

Figure 2

BEAM ENVELOPE - HORIZONTAL PLANE

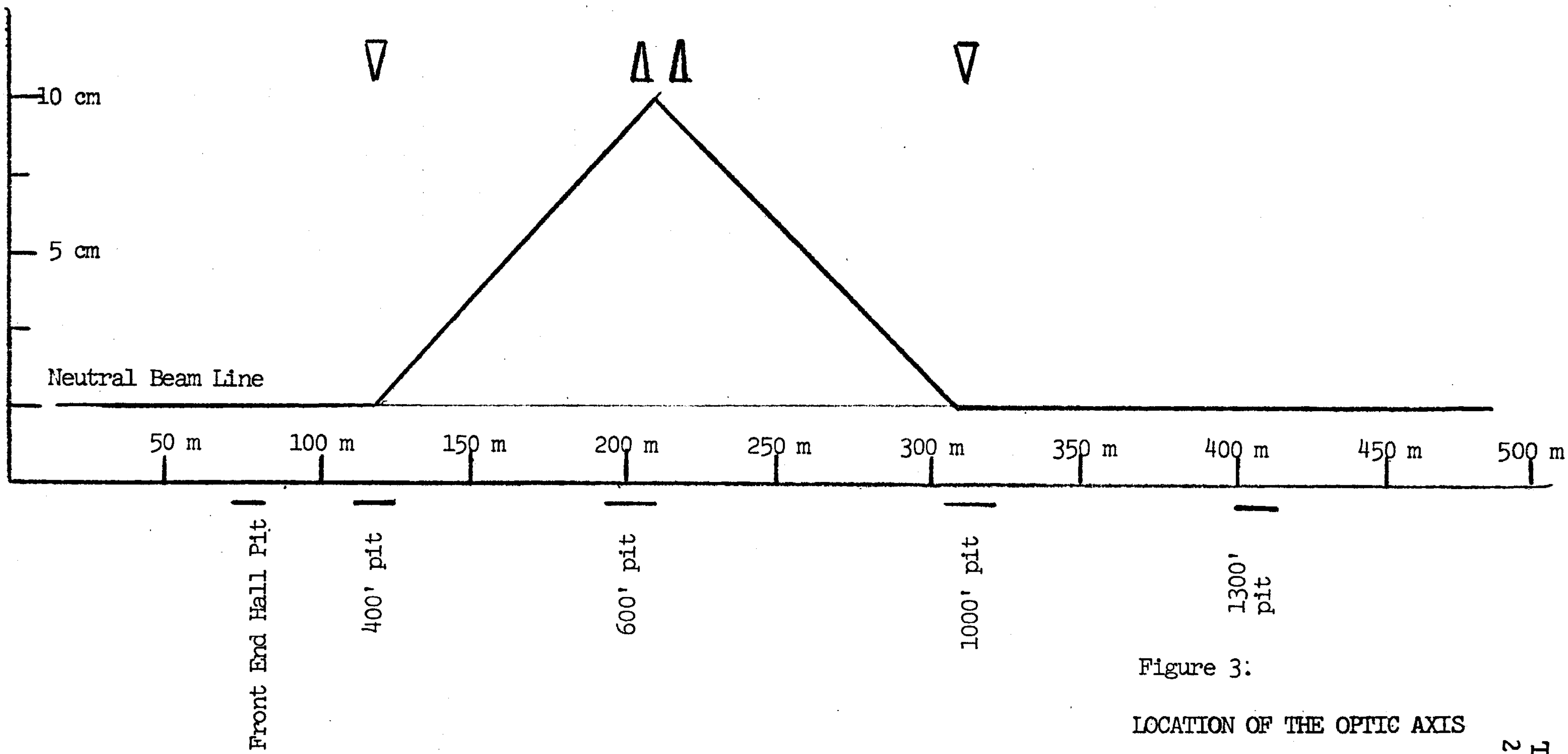

Figure 3:

LOCATION OF THE OPTIC AXIS

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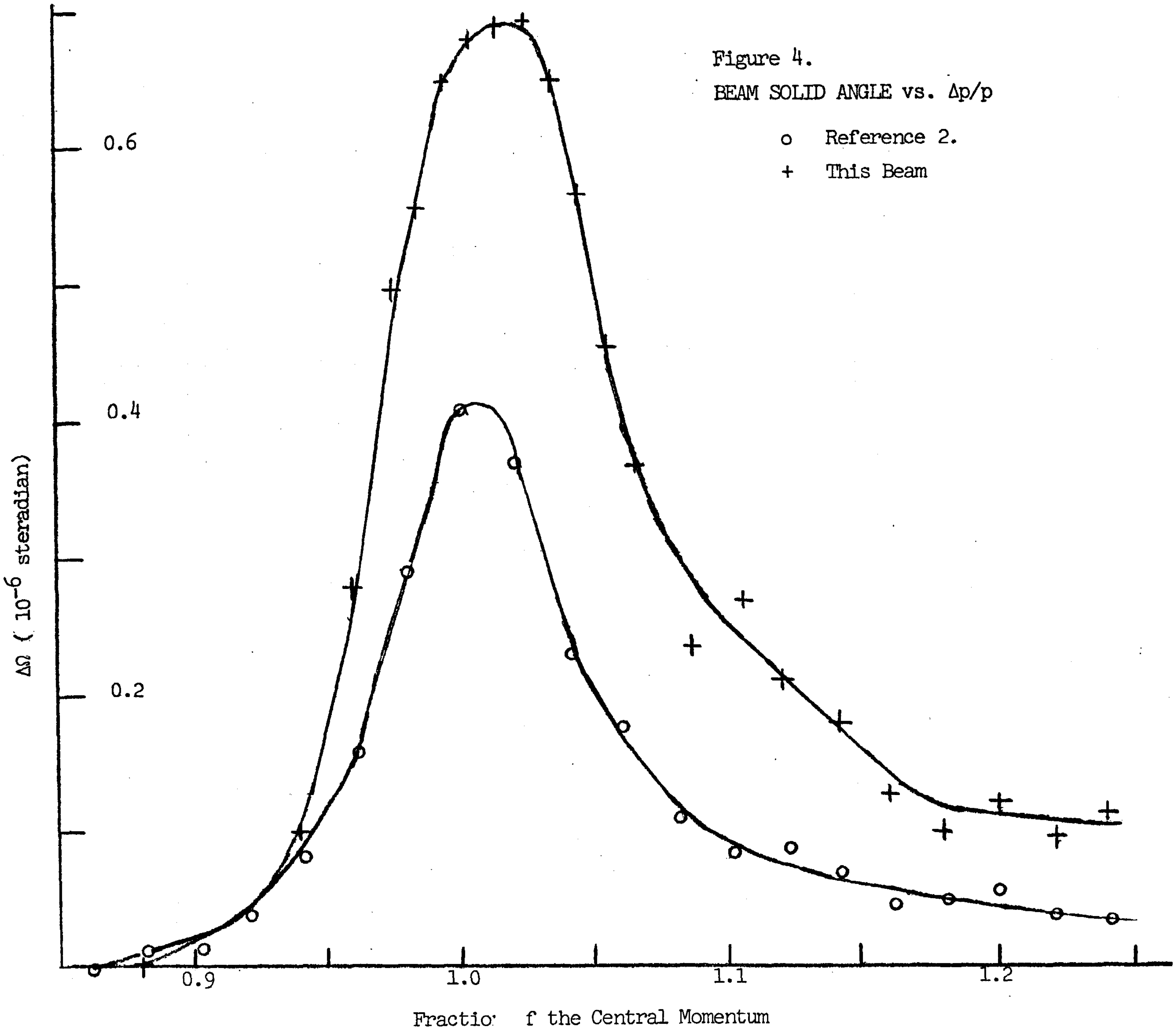

Figure 4.
BEAM SOLID ANGLE vs. Δp/p
o Reference 2.
+ This Beam
0.6
0.4
0.2
ΔΩ (10^-6 steradian)
0.9
1.0
1.1
1.2
Fractio f the Central Momentum

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Figure 5.

BEAM PROFILES AT THE FINAL FOCUS